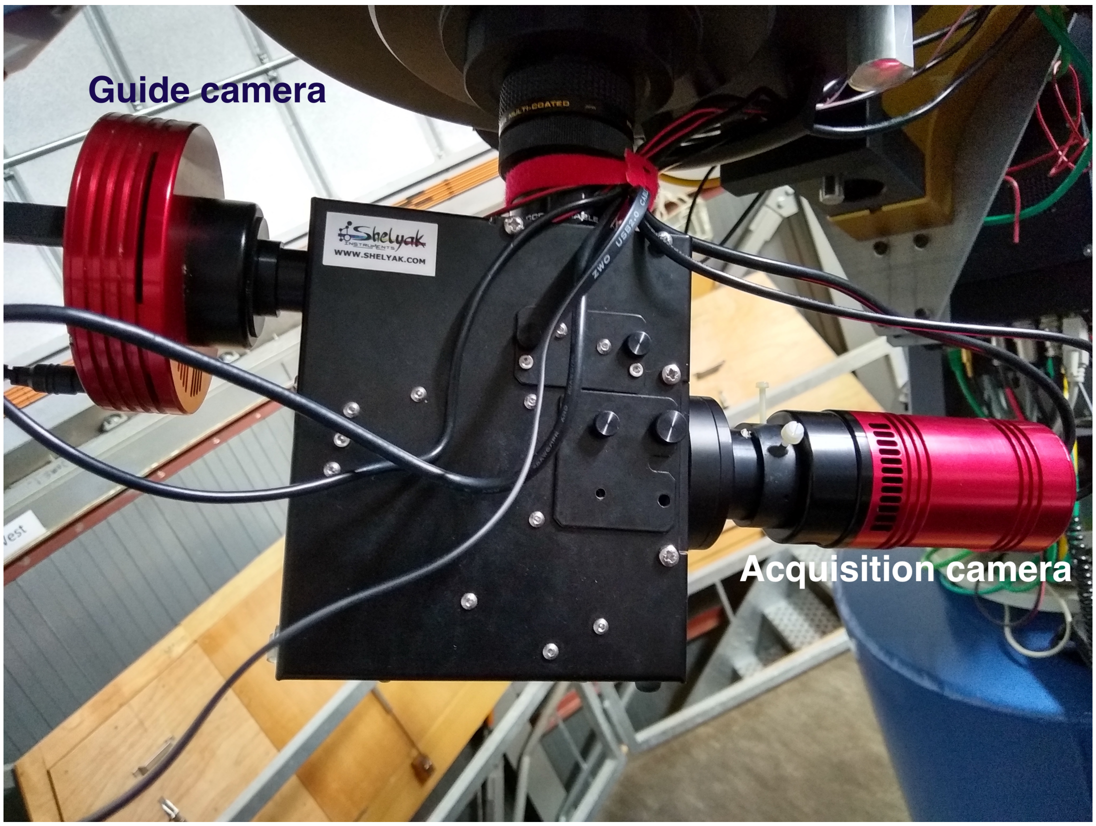
LISA spectrograph observing guide

September 20, 2021



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Contents

1 Introduction

For this course, we use the telescope in the small dome. In Figure 1 the current set-up of the telescopes and instrumentation is shown. We will be using the LISA spectrograph (see figure on the cover page for a close-up) which is permanently mounted in the prime focus of the 30 cm Meade telescope (the smallest blue telescope). This spectrograph is used for low-resolution slit spectroscopy and covers a wavelength of $\sim 3800 - 7300$ Å. The low spectral resolution makes it particularly useful for faint and/or extended objects like emission nebulae and galaxies.

The detector to record the spectra is the red cylindrical camera. For guiding, the red round camera is used. The spectrograph has in-build flat-field and Neon calibration lamps. The LISA and its calibration lamps are controlled by the "EAGLE" computer (hereafter the EAGLE) which is located in between the two blue telescopes. Using the EAGLE, the acquisition of all data is done with the software package MaximDL (Section 2). The data reduction will be done with custom written Python scripts (using Jupyter notebooks; Section 3). On top of the Meade a viewfinder scope is located to allowing to observe a large field-of-view (FOV) around the LISA target. The center of this viewfinder scope corresponds to the center of the guide camera of the LISA (see front cover figure).

2 Cookbook

2.1 Getting ready

- The telescope has a lid on top (Fig. 2, left) to protect it when no observations take place. Remove the lid so that observations can be preformed (Fig. 2, right) . To be able to reach the lid you can use the stairs located in the dome. Put the lid on one of the tables. Do not forget to put the stairs away from the telescope else the telescope might hit it during the observations.
- If the desktop computer is off in the dome, please turn it on.
- Switch on the mount manually and wait until it has started up fully. The mount can be controlled manually suing the physical keypad (Figure 3) or using the "10 micron Virtual Keypad" on the desktop computer (thus not on the EAGLE).
  - Click on the "10 micron Virtual Keypad" program on the desktop to open the program.
  - Click connect in the 10micron Virtual Keypad; Figure 3 right panel). This virtual keypad is an exact copy of the physical keypad of the mount. It works identical and shows the same information in the display (Figure 3 right panels).
- Check if the EAGLE is on and if it is not on switch it on (see Section 4 for more information on how to switch on the EAGLE). We will do the data acquisition on the EAGLE. However, the EAGLE does not have a screen attached to it, so we will use the desktop computer to open a remote desktop to the EAGLE
  - If the EAGLE remote desktop is not already running: on the desktop computer, click on the "EAGLE Zonnekoepel.RDP" icon to open a remote desktop on the EAGLE. A window as soon in Figure 4 should open. In the middle of this window the "EAGLE Manager" should be shown. If not shown, you can open it using one of the icons in the icon bar at the bottom of the window. With this "EAGLE Manager" you can control the LISA spectrograph.

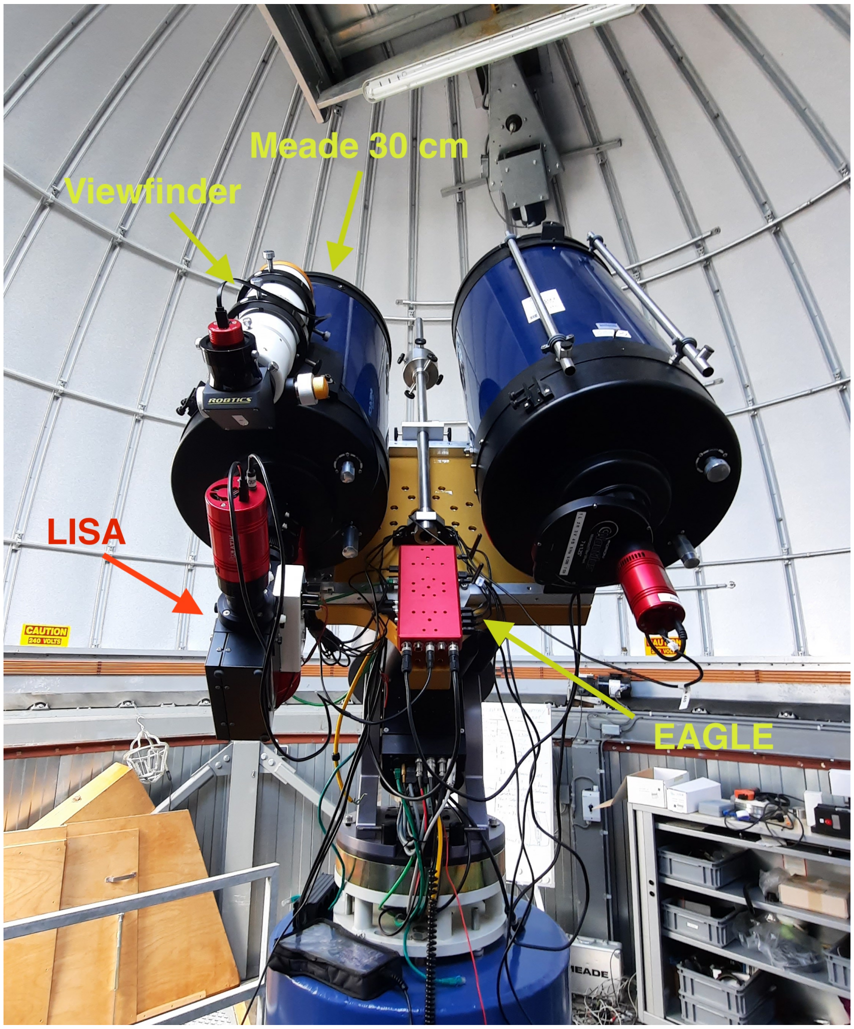

Fig. 1: *The instrumental set-up in the small dome.*

- The EAGLE Manager should be connected already to the EAGLE itself but sometimes this connection is lost. This can be checked by looking at the value given in the middle of this program for ”POWER CONSUMPTION”. In the case of Figure 4, this value is ”0 W” but it should be ”6.0 W”. This indicates that the EAGLE Manager is not connected to the EAGLE itself. To connect it properly, click ”ADVANCED SETTINGS” in the manager. A new window will pop up (see Fig. 5, left). In this window, click on ”RECONNECT” and then ”OK”. This will reconnect the EAGLE Manager to the EAGLE. This can be checked again by looking at the ”POWER CONSUMPTION” which should say ”6.0 W” (Fig. 5, right).
- When the EAGLE Manager is properly connected to the EAGLE, it should also be connected to the LISA. This can be seen in Figure 5 (right panel) where at ”A” and ”B” in the figure the ”Lisa Guide” and ”Lisa Acquisition” are listed as ”ON” (compared to ”OFF” in Fig. 4). However, the LISA camera’s are not yet on; it only means that the EAGLE has connected to them. To switch them on, click on the ”LISA” button indicated by the number ”3”. This will turn the camera’s on and if you are in the dome you can hear them making noise now. In Figure 6 (left) you can see that the LISA camera’s on because the button ”3” has turned green. Now these camera’s can be used to obtain data using the LISA spectrograph.

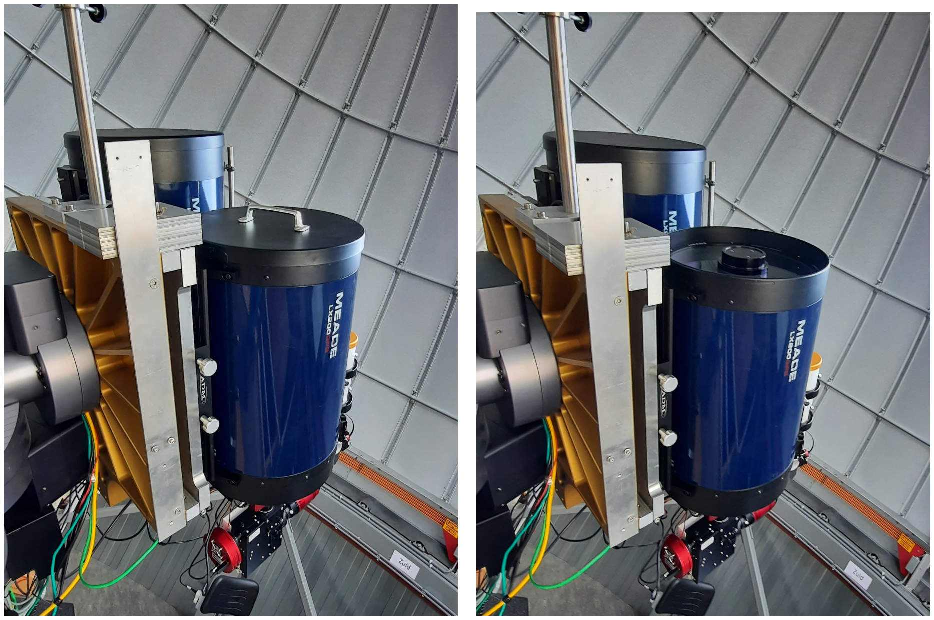

Fig. 2: The 30 cm Meade telescope with the lid on (left) and removed (right)

Fig. 3: The physical keypad (left) of the mount and its corresponding virtual keypad (right; called the "10micron Virtual Keypad") on the computer. When the virtual keypad is connected, both will show the same information in the displays (in this case the coordinates to which the telescope is pointing).

– Using the EAGLE Manager, we can also put the LISA Flat and the Neon calibration lamps on and off, using the buttons indicated by the numbers "5" and "6". In Figure 6 (right) the "LISA NEON" is on but the "LISA FLAT" is off. Note that both lamps can be on at the same time, although that will result in useless calibration data. So make sure that only the calibration lamp is on which is needed to obtain the desired calibration data. As you can see in Figure 6 (right), the "LISA NEON" button says "12V". If it does not say "12V" then the voltage is not correct. This typically happens if you had to reconnect the EAGLE Manager to the EAGLE, although it can also occur at other occasions. To set the correct voltage, do the following:
  * Click the "LISA NEON" button off so it turns red.
  * Click with the left mouse button on the "LISA NEON" button. A new window will open, which is shown in Figure 7, left. In there, "Set voltage" is "0.0" now. Set it to "12" and push the "ON" button which turns green (Fig. 7, right). This puts the Neon lamp on again which it is necessary to save the 12 V setting. Click "OK" to close the window. In the EAGLE Manager, the "Lisa Neon" button should now look as shown in Fig. 6, right. The LISA neon lamp can now be switched on and off when needed and should always have a voltage of 12 V. However, if for some reason the EAGLE Manager

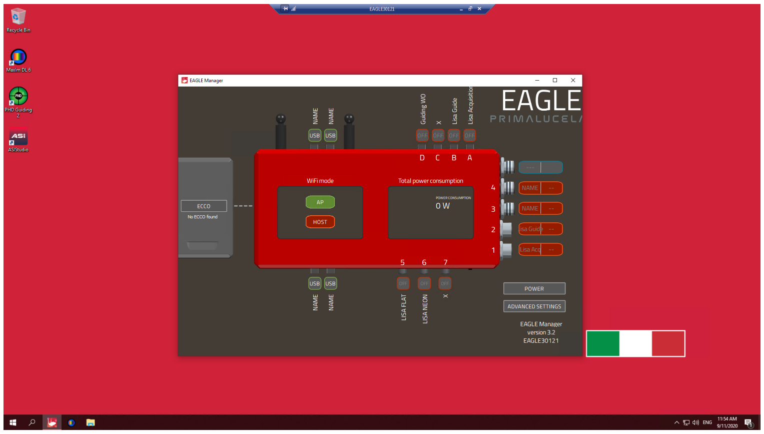

Fig. 4*: The EAGLE remote desk top window*

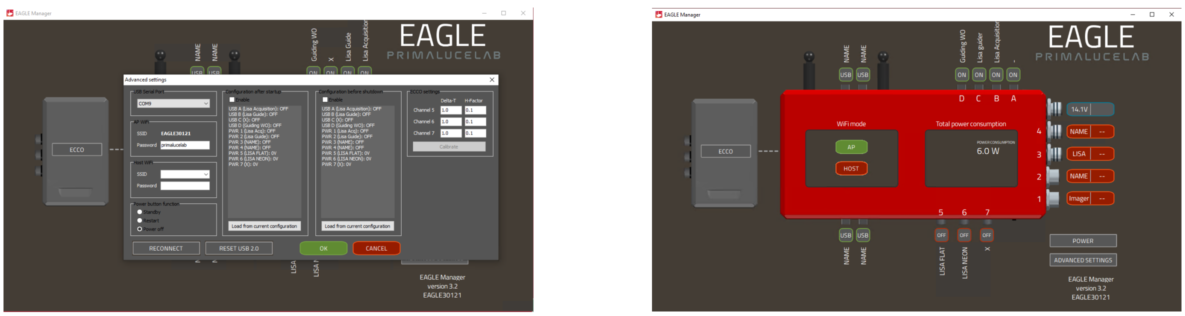

Fig. 5*: Left: The "Advanced settings" window of the EAGLE Manager. Right: the EAGLE Manager is properly connected since it says a "POWER CONSUMPTION" of "6.0 W".*

looses connection to the EAGLE itself, then this procedure has to be repeated after you have reconnected the EAGLE Manager.

∗ If you have to do this procedure for the Lisa neon lamp, you very likely have to repeat it for the Lisa flat lamp as well. So check if this is indeed necessary by putting the "LISA FLAT" button at "5" on. If it does not say "12 V", repeat this same procedure for the Lisa flat lamp.

- Open MaximDL 6 on the EAGLE (icon located on the EAGLE remote desktop; note also on the desktop computer there is MaximDL but this one should not be used because it cannot connect to the LISA). To obtain the data, we have to make sure that the MaximDL configuration is set up for LISA. For the daytime observing run we will start op one MaximDL session but for the nighttime run two, one for the acquisition of the data and one for displaying the guide image.

  – **For the daytime run:** Start up MaximDL and configure it for both the acquisition as well as the guide camera. To do that use: File → Configuration → "LISA_Acquisition_Guider" → Load (Fig. 8). MaximDL will restart.

    After MaximDL has restarted, click on View → Camera Control. This opens the Camera Control window with both camera's set to "ASCOM" (Fig. 9; if not, see Section 4 to correct this); click on "Connect" to connect the two cameras. Sometimes MaximDL gives an error that it cannot connect to one (or both) of the cameras. If that happens, first check if button "3" is green. If that is not the problem, try rebooting the EAGLE and start from the beginning. If MaximDL has connected to the cameras, click "Coolers" on to cool the detectors to the

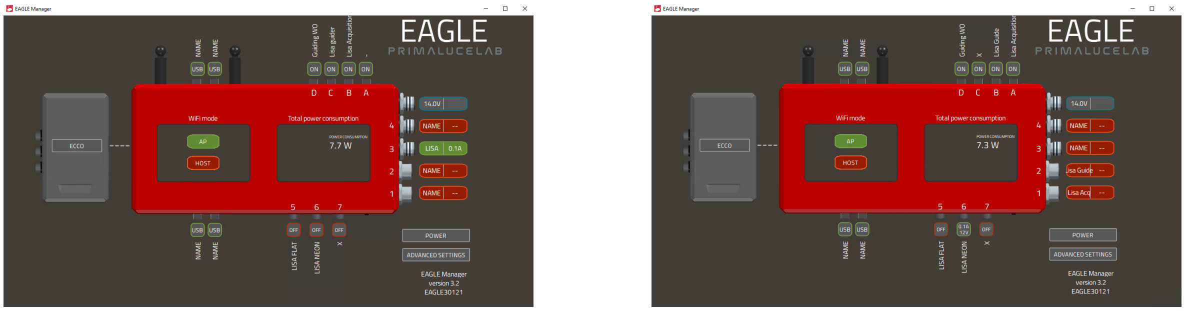

Fig. 6: Left: the LISA camera's are on as indicated by the green buttons at "1" and "2" in the EAGLE Manger. Right: the LISA Neon calibration lamp is on, indicated by the green button at "6". Also note that it says the correct Voltage of "12V" in this button.

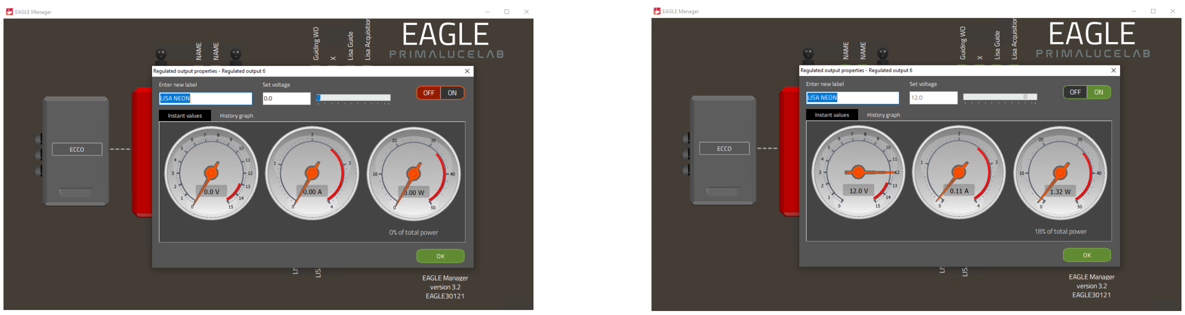

Fig. 7: The window in which you can set the voltage of the neon lamp. Left: the voltage is incorrectly set to 0.0 V; right: the voltage is now correctly set to 12.0 V.

desired temperature (Fig. 9 right; target temperature is -20° C; during daytime observing -20° C might not be achieved because of the potential high temperatures in the dome; this will not be a problem).

– **For the nighttime run:** Start up two MaximDL versions following the below instructions. The reason for running to versions of MaximDL is allow for the guide image to continuously refresh during the observations so that we can track visually the stability of the pointing.

  * Start up the first version of MaximDL and configure it for the acquisition camera. To do that use: File → Configuration → LISA_Acquisition_only → Load (Fig. 8; MaximDL will restart). Click on View → Camera Control. This opens the Camera Control window with "ASCOM" set for "Camera 1" (if not, see Section 4 to correct this); click on Connect. Click Coolers on to cool the CCD (target temperature is -20° C).
  * Start up a second version of MaximDL and configure it for the guiding camera. Use: File → Configuration → LISA_guiding_only → Load (Fig. 8 left; MaximDL will restart). Click on View → Camera Control. This opens the Camera Control window with again "ASCOM" set for "Camera 1" (if not, see Section 4 to correct this); click on "Connect" and put the coolers for this CCD on as well. Similar to during the daytime run: if MaximDL gives an error that it cannot connect to a camera, make sure that button "3" is green. If that is the case, you can try to reboot the EAGLE and start from the beginning again.

Sometimes the MaximDL settings are messed up and it cannot connect correctly to the LISA. This likely has happened if somebody clicked on 'Save' in the "Configurations" panel (see Figure 8)

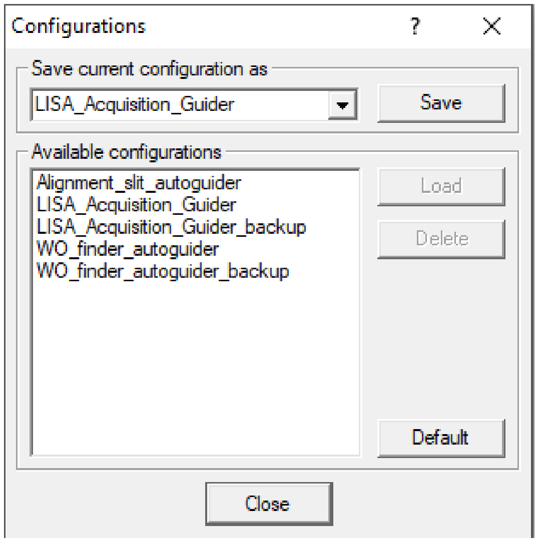

Fig. 8: The LISA configuration window. To set-up LISA properly for the daytime observing run, you have to use "LISA_Acquisition_Guider". Click on the corresponding selection in the "Available configurations" tab and click on 'Load'. Never click on 'Save'! (see Section 4 to fix the configuration issues that might arise if somebody accidentally clicked on "Save").

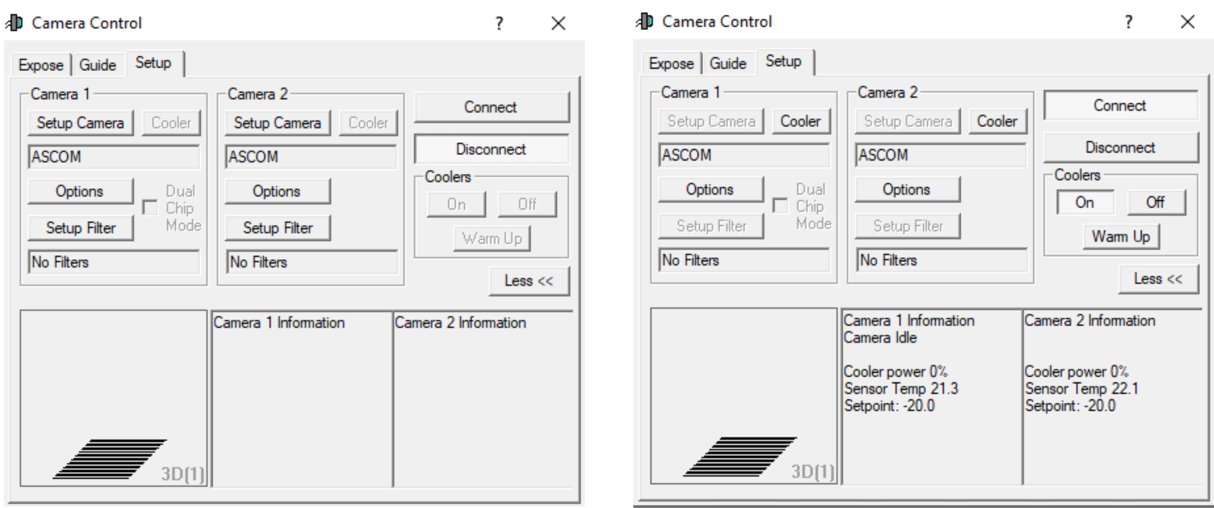

Fig. 9: The "Camera Control" window for the daytime observing run with both camera's set to "ASCOM". Left: the camera's are not connected; right: the camera's are connected and the coolers have turned on (just turned on because the actual temperatures are still much higher than the "Setpoint" temperatures).

and the wrong settings were saved in (one of) the LISA configuration files. To solve this issue, see Section 4.

- For nighttime observing, start the Al's Reticle program (icon is on the desktop; note it is located on the desktop, not the EAGLE), which produces a red cross-hair overlay with adjustable intensity. This can be placed anywhere on the guide image during the observing and it is a very useful tool for guiding the telescope during the observing run.

- All files that will be obtained during the observations should be saved in the directory (on the EAGLE desktop there is an icon 'DATA' which gives you access to a top level directory of where the files needs to be stored)

```
C:\DATA\yyyymmdd
```

with yyyymmdd the date of the observing run (for instance `20200914`; for the night time observing run, is the date of the evening, even if the exposure starts after midnight). Create the directory if it does not exist yet.

2.2 Calibration

To obtain the calibration images it is required that the dome and telescope are closed and the lights in the dome are off in order to avoid stray light contaminating the images.

- Wavelength calibration is needed to convert the pixel scale of the CCD to an actual wavelength scale. In the EAGLE Manager, switch on the Neon lamp (see Fig. 6 right). In the MaximDL "Camera Control" window click on the "Expose" tab and make sure the frame type is set to "Light", the 'Camera 1" and the "Single" radio buttons are finked, and expose for 20 to 30 seconds[1]. An image should appear as shown in Figure 10. Take at a significantly large number of exposures (typically 20 to 30, preferable more; so that also the fainter lines in the blue part of the spectrum will get a reasonable signal to noise ratio) and save them (the best way to do that is using Autosave as explained below); they will be combined during the processing of the data to increase the signal-to-noise ratio of the lines. When all exposures are taken, switch off the Neon lamp in the EAGLE Manager.

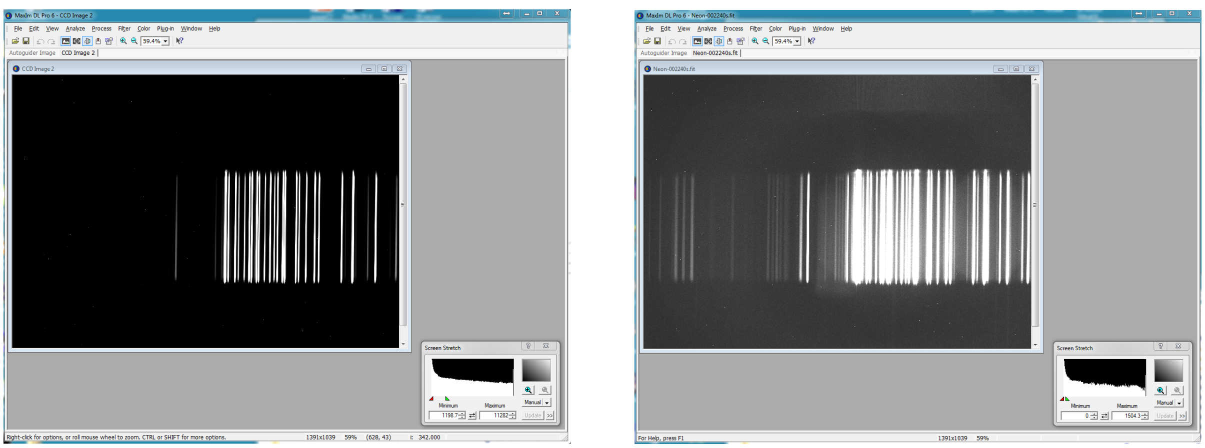

Fig. 10: *The 2D spectrum obtained during a Neon lamp calibration exposure. The right figure shows the same data as the left figure but with the gray scaling (using the stretch window shown in the bottom right corners) adjusted to also see the fainter lines to the left of the bright lines (this is only for display purposed; the data are not altered).*

Note: The most efficient way to take a sequence of exposures is to use Autosave in the Expose tab: click on Autosave to enter the setup (see Figure 11 left): define the filename ("Autosave Image") and for each slot the Type ("Light"; this will be "Dark" when using Autosave to take dark frames), Suffix ("_20s"), exposure time (20)[2], binning (1) and number of exposures in Repeat (5 but increase to 20 or 30). Define the target directory under Options ("Set Image Save Path"; leave Auto-subfolder unchecked; check "Group by Slot"). If you want to delay the first exposure

[1] An example of the "Camera Control" window is shown in Figure 11 (right panel). In the bottom part of this figure information is giving to monitor the progress of the exposure. E.g., it was image 1 out of a series of 5, the exposure has progressed for 174 seconds, and the temperature of the CCD was 3.2 Celsius (note the set-point was -10 Celsius but this was an exposure during the day when it was about 30 Celsius in the dome so the CCD could not be fully cooled).

[2] In Figure 11 the exposure times are listed as 240 seconds; however, it would be better if indeed 20 seconds was used instead because with 240 seconds many of the calibration lines used in the reductions of the data are also saturated.

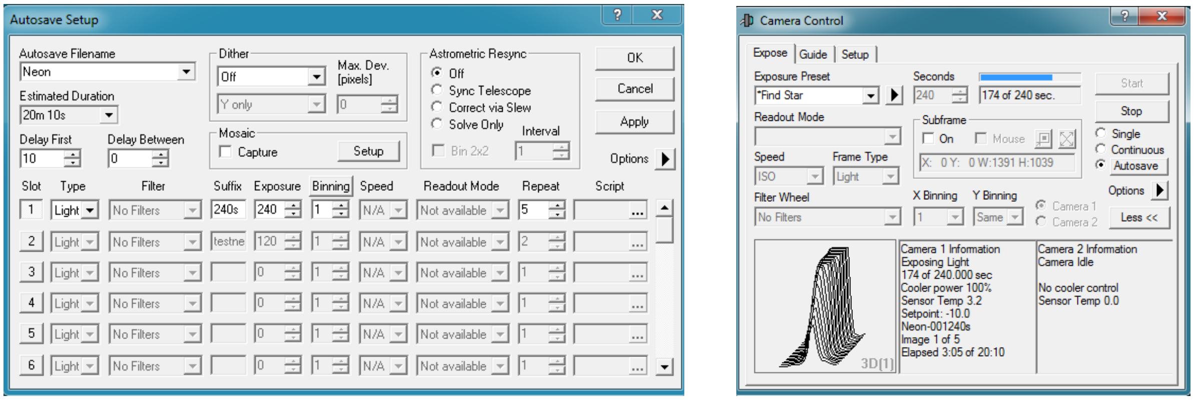

Fig. 11: *Left panel: the Autosave Setup window with the appropriate settings (although see footnote 2) to obtain a sequence of 5 Neon calibration exposures. Right panel: the corresponding Camera Control window after Autosave has been checked and the exposure has started.*

(e.g., to be able to put the lights off) insert the delay time in ”Delay First” (e.g., set it to 10 seconds). Confirm with Apply and click start in the ”Camera Control” window. Write an entry in the Observing Log that you have obtained the neon calibration files.

- Flatfield calibration is done to correct for the variation in gain of the CCD. To make flatfields switch on the flatfield lamp in the EAGLE Manager (make sure the Neon lamp is indeed turned off). Set Frame type to ”Flat” in the MaximDL Expose tab (in single exposure mode; if still in autosave mode, the frame type cannot be changed) and take a trial exposure of 10 seconds. When complete the flatfield image is shown in MaximDL. Check the maximum pixel values in the image. The maximum value any pixel can have is 65.536 (2^{16}) and none of the pixel should be saturated. A good value would be approximately 80% of this saturation limit, thus around 50.000. The number of counts per pixel scales directly with exposure time so adjust the exposure time to reach approximately 50.000 counts per pixel max (it does not have to be exact; any value between 45.000 and 55.000 would be fine). Typically the exposure time will be around 30-40 seconds and the final 2D flat field image should look like Figure 12 (left panel). Save the final exposure (e.g., `ffa40s.fit`, uncompressed, 16 bit) in the same directory. Take several more flatfields to increase the signal-to-noise ratio during postprocessing. This can be done using Autosave (change the appropriate field in Autosave to the correct values; i.e., Autosave Filename, Type, Suffix, Exoposure, Repeat). When all flatfield exposures are complete, switch off the flatfield lamp in the EAGLE Manager. Make an entry in the obsevation log that you have obtained a sequence of flats.

- Dark frames are needed to subtract the dark current (noise) from the science images. Since the dark current scales directly with exposure time, the dark frames need to have the same exposure time as the science frames. Therefore, darks are typically done after the science frames are performed so one actually knows the used exposure time. Since the dark current also scales with the temperature, the temperature of the CCDs during the dark exposures need to be (roughly) that of the temperature during the science exposure (i.e., important if the darks are taken after the observing run is already complete; so then do not forget to switch on the CCD cooling; best is to make the dark frames right after the science observations have ended). To make dark frames make sure the calibration lamps (Flat and Neon) are switched off in the EAGLE Manager, set the frame type to ”Dark” in MaximDL Exposure tab, cover the telescope (put the lid back on), put out all the lights in the

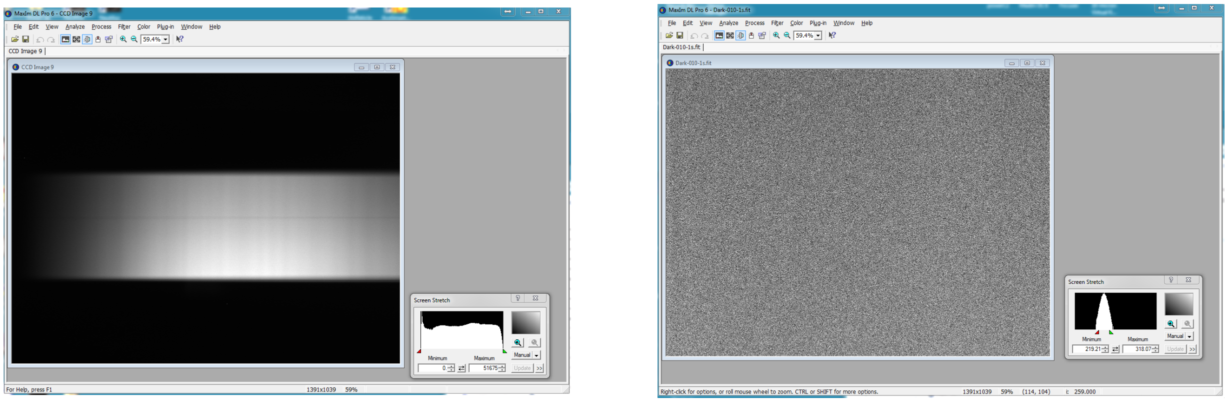

Fig. 12*: Typical example images of a 2D flatfield spectrum (left) and dark frame (right).*

dome (to avoid light leaks), and expose the CCD using the same exposure time as used for your spectra. Save (in the same directory) as dark[exposure time]a.fit (for example; with [exposure time] the actual exposure time you used), uncompressed, 16 bit. Use Autosave to take a series of dark frames (setting again the appropriate fields correctly). An example image of a dark frame is shown in Figure 12 (right panel).

2.3 Object exposures

During the course we will perform two observing runs. One during the daytime to practice observing and the data reduction/analysis, and one during the night to obtain data of our astronomical target. The daytime observing should be performed when there is no chance of rain. It does not matter if the sky is fully clear (blue sky observing) or that only clouds are visible (cloud observing). The procedure for the daytime observing is explained in detail in section 2.3.1 and the nighttime observing in section 2.3.2.

Open the dome. To move and open the dome use the manual control box near the stairs (which controls the box that hangs from the dome). Open the dome as far as needed (but not more during nighttime observation since this will only increase the light pollution from Amsterdam in the spectra). During the observing runs, the dome should be oriented such that the telescope is not blocked by any part of the dome. *Note: there is a strange issue with the dome control boxes, causing frequently a delay between the boxes. You might have to push the buttons on the box near the stairs several times before the dome reacts. In addition, the dome might continue to open or close for a few seconds even after you have let go of the buttons.*

Since our object to be observed during daytime observing is a diffuse target covering the whole sky, the guide camera will not be used during daytime observing (nothing to focus on). However, the guide camera is very important during nighttime observing.

2.3.1 Daytime observing

For daytime observing, we will take observations of three parts of the sky but we will first take some spectra of the calibration lamps present. Although the LISA has internal calibration lamps itself (see Section 2.2), we still also take spectra of these lamps in order to practice taking spectra and analysing such calibration spectra ourselves. You will have to identify the observed lines and determine that you indeed observed Krypton and Water Vapor.

In the dome, a portable calibration unit is available (see Fig 13) as well as two calibration lamps (containing Krypton and Water Vapor). Plug the unit in a power socket (if necessary, extension cords are available in the domes) and put one of the calibration lamps in it. Turn it on and you will see it start glowing. One of you can stand on one of the portable stairs and hold the lamp up high; another student can point the telescope at the lamp and take several spectra. **Do not hold the lamp above the telescope because if by accident you drop the lamp it can fall onto the telescope and damage it (i.e., damage the corrector)!** When done, replace the lamp with the second lamp and repeat. Be careful when removing the lamp because it will heat up significantly. If necessary, let it cool down before removing it. Do not forget to add these observation sequences in your observing log.

- If the sky if fully blue, you can point at the zenith, halfway between the horizon and the zenith, and just above the horizon. In this way, you can study later how the brightness and spectral shape changes with altitude during a blue sky.
- The sky is partly cloudy and still see blue sky, point at a part which is blue and point at two different clouds which have different brightness. In this way, you can study later the difference between the blue sky and a cloud, as well as between two clouds which are not equally bright.
- If the sky is fully overcast but the clouds have different brightness, point at three different clouds which indeed differ in brightness. In this way, you can study how the spectra changes with different brightness of the clouds.
- Sometimes the sky is fully overcast and the clouds are very homogeneous in brightness. In that case, take two spectra of the clouds at different parts of the sky. In this way you can check if indeed the clouds are uniformly bright. In addition, you can observe one of these different options:
  - Point the telescope at the inside of the dome and take a spectrum. In this case, you can investigate how a reflected sky spectrum (through reflection in the dome) differs from one that has been taken directly at the clouds.
  - Observe one of the targets given in the next bullet point where the alternative program when it is raining is listed.
- In case you can not open the dome due to rain or heavy winds, you can follow the following alternative program:
  - Point the telescope at the zenith and put the light in the dome on. Take a spectrum of this lamp. You will notice that the lamp has several emission lines and you can, in the processing and analysis phase, investigate which elements are present in the lamp.
  - One of the students should turn on their phone and another student should point the telescope at the phone (**do not hold the phone above the telescope because you could drop it and damage the telescope!**) and take a spectrum. In addition, the 'Torch/Flashlight' of the phone can be switched on and again a spectrum can be taken. In this case, you can determine what kind of spectrum a phone emits and determine whether or not the 'Torch/Flashlight' exhibits the same spectrum.

Since we want to study the differences in brightness between different parts of the sky, the total exposure times for these different parts should be the same. So make sure that the exposure times are such that when later the data are combined, you can reach the same total exposure time.

***Fig. 13**: The portable calibration unit with examples of calibration lamps.*

With the keypad (either the physical or the virtual one; Figure 3 left) you can control the mount (and thus the direction to which the telescope is pointing). The TA can explain you how the keypad works. When you have moved the telescope to your target, use the dome control buttons to put the dome into place so that the light of your target reaches the telescope (i.e., nothing is blocking the view of the telescope).

Before doing the science frames, make sure you have obtained the the wavelength and flatfield calibration exposures (see section 2.2). Typically 5 flats and 20-30 Neon frames are sufficient. The dark frames will be obtained after the observing run is over. As an exercise you can also look at the guide camera to see how it looks during the daylight run. For that go to the ”Camera Control” window (Fig. 9), go to ”Expose” and make sure that the read out camera is set to ”Camera 2”. Now you can take an exposure of the guide camera (the exposure time can be very low, such as 0.01 seconds, to make sure that the detector is not saturated) and the resulting image should look like Figure 14. Clearly the slit of the LISA is visible as well as many imperfections on the detector (but we do not have to worry about them). Save this image and then switch the camera back to ”Camera 1” to get acquire the science frames.

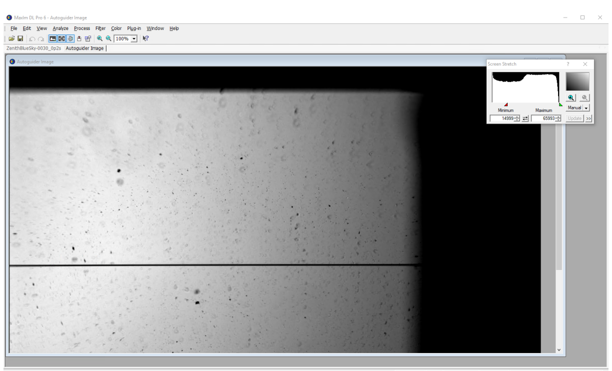

***Fig. 14**: A typical example of the guide camera image during the daytime observation run which clearly show the slit of the LISA.*

Make sure the lights in the dome are off to inhibit any contamination from those lights during the science exposures. Since the sky is very bright during the day and we have a slit, the typical exposures times are very short (of order seconds, depending on exact brightness of the target) for the science frames. But this has to be tested by obtaining trail exposures with different exposures times. In the MaximDL Camera Control window (Exposure tab) set the frame type to ’Light’.

In the test image (that will appear in MaximDL), none of the pixels in the 2D image of the spectrum

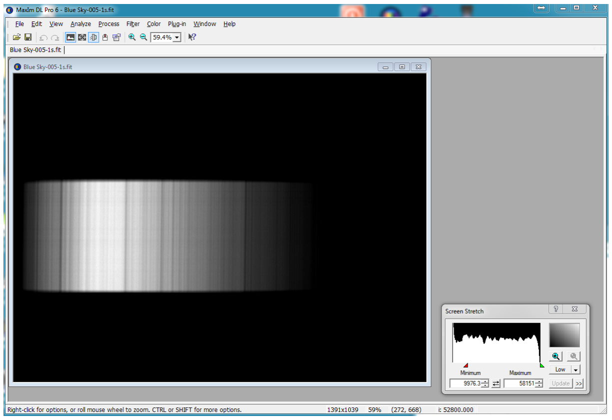

Fig. 15: *A typical example of an image of a 2D spectrum of the blue sky. Clearly the blue sky is mostly a continuum spectrum but with many absorption lines superimposed on it (visible as the dark lines).*

should exceed the maximum pixel value of 65.535 because this means that the pixel is over exposures. The best results will be obtained if none of the pixel is overexposures but that they still have high values (e.g., $\sim$45.000-55.000 counts for the brightest pixels; about 80% of the saturation limit). Adjust the exposure time until you reach roughly the desired values. Use the Autosave option to take the science frames (using the appropriate settings in Autosave). Since the exposure times are likely very short, you can take quite a number of images in a short time. Typically 60 images would be a good number to obtain. The more frames, the higher the signal-to-noise ratio of your spectrum will be during the post-processing phase.

When done with this particular part of the sky, repoint the telescope to another position and repeat the procedure. Do the same for the third pointing until all observations have been performed. Do not forget to add every observation as an entry in the observing log.

After the science frames have been done, the dark frames have to be obtained. The dark frames should have the same exposure time as the science frames. Close the dome and move it to its home position (marked at the dome). Close the telescope and put the dome lights off. It has to be as dark as possible to avoid any contaminating light reaching the CCD. Take several dark frames as explained in section 2.2 (e.g., using the Autosave option). Since the science exposure is short, taken dark frames will not take much time and 10 dark frames are quickly taken. However, very likely the different sky positions required different exposure times so make sure you have dark frames for each exposure time you use.

Shut-down procedure: When all images (calibration and science) are obtained, everything has to be closed and shut-off. In the MaximDL Camera ”Control windows” go to the ”Setup” tab and disconnect the camera’s. Exit the MaximDL session. In the EAGLE Manager put both LISA camera’s off, as well as any calibration lamp if it was still on. If not already done, make sure the dome is closed and put in its home position. Use the mount keypad (either the physical or the virtual one) and park the telescope. The TA can show you how to do this. Make sure you put the mount off (the red light is off). Also make sure the telescope is closed (the lid is on it). Close the EAGLE remote desktop. Fill in the APO technical observation log (see the slides of lecture 2 for the link) on using a browser on the desktop. Put the lights off in the dome when leaving the dome.

Location of your data: If everything was done correctly, your data files should be on the EAGLE in the directory

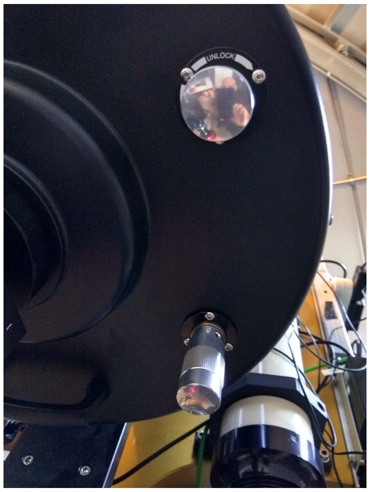

Fig. 16: *The manual focus knobs of the Meade telescope. The top knob is to unlock the focus (the mirror). The bottom knob is to manual focus the telescope when the mirror is unlocked. When the telescope is in focus, do not forget to lock the mirror again but turning the top knob counter clock wise!*

```
C:\Users\APOuser\DATA\Spectroscopy\LISA\yyyymmdd
```

with yyyymmdd the date of the observing run. These data can be transferred to you by using wetransfer.com. Go to this website and follow the instructions. You can transfer the whole directory at once (so you do not have to upload each file separately).

2.3.2 Nighttime observing

In the Power Control window, switch on the mount if you have not switched it on (see section 2.1 for more details and in case the mount does not switch on correctly). With the keypad (either the physical or the virtual one; Figure 3 left) you can control the mount (and thus the direction to which the telescope is pointing). When you have moved the telescope to your target, use the dome control buttons to put the dome into place so that the light of your target reaches the telescope (i.e., nothing is blocking the view of the telescope).

During nighttime observing, we will make use of the guiding camera. The field of view of the guiding camera is rather small ($\simeq 4' \times 5.5'$), which means that at the first pointing the target might sometimes not appear in the field. However, usually the source should not be located far away from where the telescope is pointed. In such cases, you can use the telescope keypad to move the pointing slightly in a random direction and try to sample the nearby region until you see the target appearing in the field of view of the guiding image. For weak diffuse sources, you might wish to use the camera control window of the guide image to rebin the image during read out. This will make diffuse, faint objects easier to spot. But remember to put the rebinning back to the original settings after you have found your object!

Per target several steps have to be performed to obtain the data.

- **Manual focusing the telescope:** Sometimes when starting the observing run, the focus of the telescope is not set for the LISA spectrograph.
  - Go to a near-by star of approximately 5^{th} magnitude and make sure it is visible in the guide image. A brighter star is no good because it will be too bright to focus on because it will always saturate the guide camera when in focus.
  - Use the large knob on the back of the telescope to unlock the mirror (see Fig. 16; top knob in this figure). Rotate this knob clock wise to unlock the mirror.

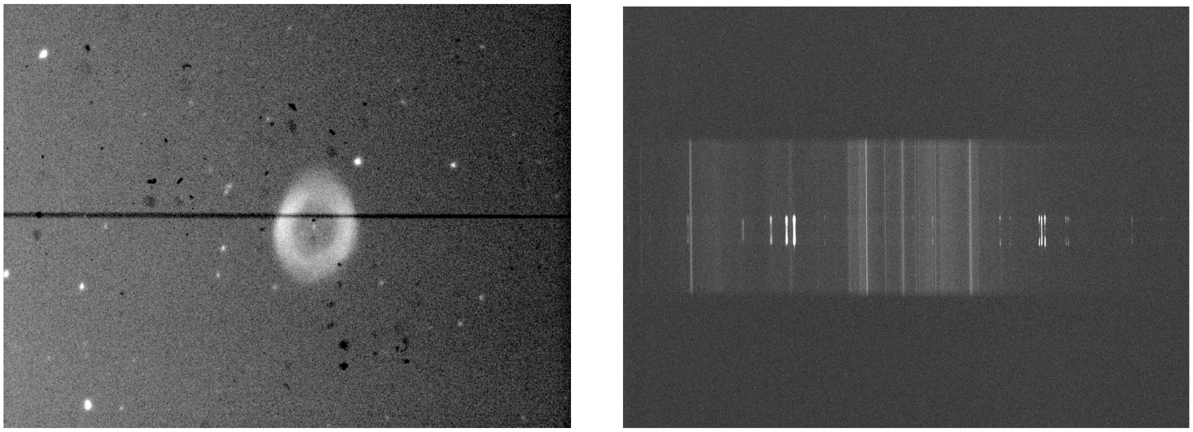

Fig. 17: Left: the guide image (30-s exposure) of the Ring Nebula. The nebula is clearly visible as well as the slit. In addition, several field stars are visible; the black spots and smudges are artifacts of the CCD. Right: the corresponding 2D spectrum of the Ring Nebula (200-s exposure). The lines that only cover a small part of the CCD are the source lines. Clearly some lines are brighter at the end points which correspond to the ring of the nebula. The lines that cover the whole CCD region are sky lines.

  - When the mirror is unlocked (see previous step; please do unlock the mirror else you might damage it) you can use the other knob to focus the mirror. You can move it clock wise and counter clock wise. Look at the guide image to see how the focus changes. Move this knob until the star is in focus.
  - When the star is in focus, rotate the lock knob counter clock wise to lock the mirror again. Not locking the mirror will cause it to shift slightly when the telescope rotates and therefore loosing it focus!
  - Later, when your target is in the guide image, you can further focus your target by using the above steps.

- **Exposing the target:**
  - Both MaximDL sessions should be open; if not open them following the procedure outlines in section 2.1. Slew to the target (using either the physical or the virtual keypad) and set the guide image (in one of the MaximDL windows) for continues exposures. An exposure time of a few seconds would typically be sufficient to see most of our targets easily in the guide image. However, for very faint objects (like M82) the source might not be visible and longer exposure times might be needed. In addition, you can temporarily rebin the guide image to enhance sensitive until you have found your object. Remember to set the binning back to 1x1 after you have found your source on the guide image (you might then have to exposure longer to again see your object clearly).
  - Make sure your object is centered on the slit in the guide image (e.g., Fig, 17, left). It is important that the object is centered as much as possible. It is important to have ample background (due to sky light) regions outside the source region in the 2D spectrum image to extract later, during the processing of the data, also the sky-background spectrum. Putting the source close to an edge, will result in only one side being useful and might give complications during the data reduction.
  - For certain projects, it is important to be able to position the slit on a certain part of the source (i.e., to align the slit completely with M82) and you need to rotate the image. For this you

Fig. 18: *M82 on the guide image during rotation. The left most image is the starting image and clearly the slit does not fall on top of M82. The middle panel shows M82 in the correct orientation but during the rotation it moved below the slit. The right most panel shows M82 on top of the slit. The images are 60 s exposures but shorter time can be used to still see the source.*

have to manual rotate the LISA spectrograph (note: the whole instrument as it is attached to the telescope; *do not rotate the red camera's!*). Talk to your TA for how to do this. An example of how the guide image will look during rotation is shown in Figure 18. The left panel shows M82 at the start of a particular observation run. For the M82 project is important that the slit covers the full galaxy so the image has to be rotated. The middle panel shows the image after the image was rotated but clearly now the target does not fall on the slit. To correct for that, use the keypad to move the target in such a way that the slit covers the whole galaxy.

- When your target is correctly located on the slit, set the exposure time in the Expose tab of the Camera Control window (in the other MaximDL session) and start exposing. First take a trail exposure to see how good the spectrum looks like. The spectrum should like Figure 17, right. For bright targets make sure that the lines of your target are not overexposed. For faint objects, do not take too long exposures because if one exposure would fail for some reason, you loose a lot of time. It is recommended to exposure for at most 15 minutes to half an hour and perform these exposures multiple times. They can be stacked later in the processing phase to increase the signal-to-noise ratio of your spectrum. Also realize that for long exposures (e.g., half an hour) you need also dark frames of half an hours (and several of them) resulting in a significant amount of overhead time. When decided on a final exposure time for your target you can expose the source. Remember to save always the files! The best way to do a set of observations is to use the Autosave options, as explained above in section 2.2. Remember that to achieve the best signal-to-noise of the final spectrum, the more exposures obtained the better. To be able to add the exposures, make sure that your target always falls on the same part of the slit. You can do this using the cross hair as outlined below.
- Due to the corona crisis, we will stay in the dome the whole time and these steps should not be followed: A sequence of exposures should not be done in the dome because for the guiding the computer screens have to be on and that produces contaminating light. Therefore, before start of the sequence make sure the dome is positioned such that the telescope points clearly at the source, preferable a bit to the edge of the opening so that the telescope has ample time to track the target without the dome blocking the view of the telescope. This tracking will typically take 1 to 1.5 hours before the other edge is reached, so it would be wise not to have an exposure sequence that last much more than an hour because that means moving the dome halfway the exposure causing vibration in the instruments and therefore deterioration of the quality of the data. When the dome is set properly, use a delay in Autosave (e.g., 30 seconds)

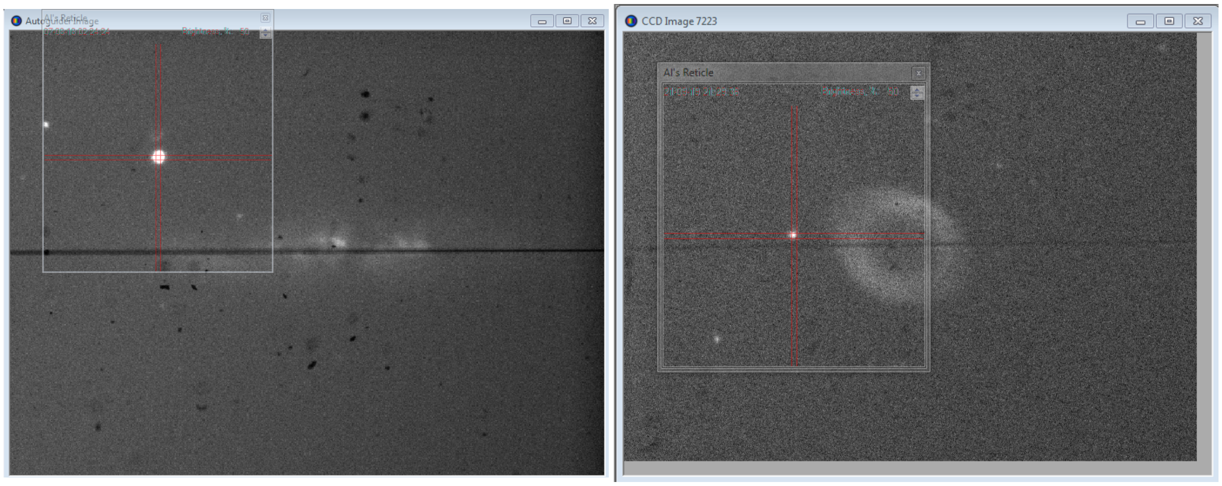

Fig. 19: *Guide image of M82 (left) and the Ring Nebula (right) with the cross hair on a field star that will be used to ensure the object is always on the same position in the slit.*

and then hit expose. Put of the computer screens so that the dome is fully dark and then go down to the control room (C4.121) where you can use one of the computers to remotely (using TeamViewer) log in to the dome computer and the next steps can be performed using this remote connection.

– During the exposure of your target, keep an eye on the image of your target in the guide image (in the other MaximDL session). Both camera's can exposure at the same time. Adjust the pointing to keep the object on the slit and in the same position. For you to be able to stack the individual exposures of your target during processing, it is important that your source always falls on the same position in the slit. To be able to do this, you can use the Al's Reticle cross hair (if not present open it; its icon is on the desktop; note, not on the EAGLE itself). You can put the center of this cross hair on a bright star close to your object (or on the object itself it is has bright spots). Examples are shown in Figure 19. Use the virtual keypad to make sure that the field star is always in the center of the cross hair. Figure 20 shows what happens to the data if the source drifts in the guide image (although it was always on the slit). The resulting drift of the 2D spectra on the CCD makes the post-processing of these data very challenging. Moreover, our current software version cannot handle this and only the individual spectra can be extracted and not the combined one (and thus the overall signal-to-noise is very limited). This shows the importance of keeping your target on the same position in the slit.

– Make sure to always save some of the guide images as a FITS file which will save the telescope position and several other parameters. It also can be used to reconstruct the slit position on the target.

– When all the exposures have been obtained, you can go to your next target (or the next region of the same target if you want to study variations in the spectral shape depending on position in the target).

– When all targets have been observed, take the dark frames (using the same exposure times as the targets; if this differs between targets make sure that you take the corresponding darks for each target). See section 2.2 for more information about obtaining darks. Make sure the dome and telescope is closed and the dome lights are off. Take at least several dark frames (preferably 5 but if the exposure time for your targets was very long, of order half an hour, 3 darks would be sufficient as well).

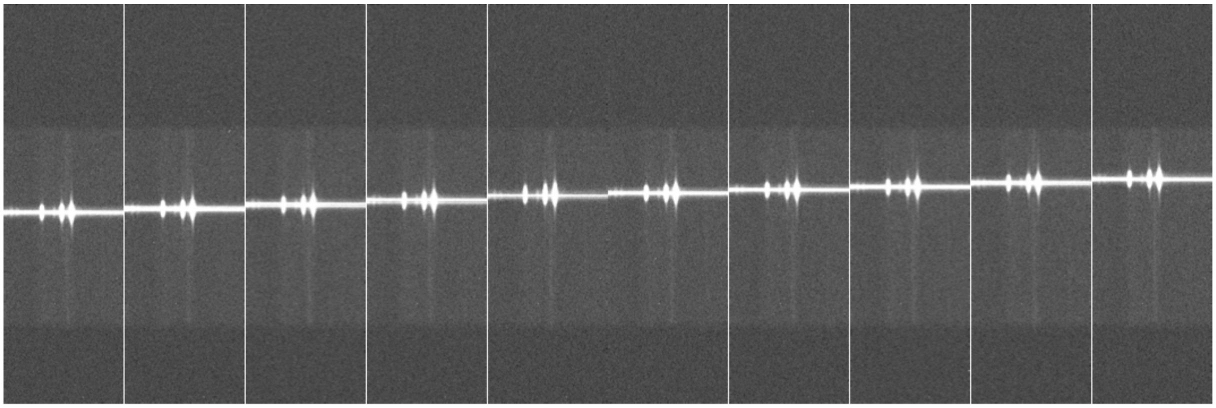

***Fig. 20**: Sequence of (part of) 2D spectra (200-s exposure each) of the Cat's Eye Nebula. Clearly during the exposures the nebula drifted to the edge of the CCD (although it was always on the slit) resulting in 2D spectra which are displaced from each other. These spectra are very difficult to combine in the data reduction software available to us and only the individual spectra can be used.*

- When all data have been obtained follow the procedure described at the end of section 2.3.1 to close everything correctly.

3 Reduction

The reduction of the data will be done using a Python notebook (Jupyter notebook; https://jupyter.org/). For this you have to have installed python 3 on your own laptop or desktop as well as the Jupyter software (for installation instructions see https://jupyter.org/install). The necessary notebook files can be obtained from the Dropbox link the teacher has sent around. However, there as several dependencies which are not standardly included in the Python installation (e.g., the scripts use Astropy; available at http://www.astropy.org/) and therefore you have to install yourself these packages (google the installation instructions). The guide lines given below are assuming that you indeed have python and the Jupyter notebook available.

The reduction pipeline is written by the teacher and the teaching assistants and it is a rather basic pipeline. Therefore, several things are not corrected for such as removing cosmic ray events. Also issues like highlighted in Figure 20 cannot be corrected for as well as a proper background subtraction of the source spectrum. Finally, removing the instrumental response is also not possible. In professional software these and other issues will be correctly dealt with to produce a final, fully corrected spectrum. However, the available basic pipeline is sufficient to create a reasonable accurate spectrum to demonstrate the different reduction step necessary as well as to be able to infer correct interpretations from the final spectra.

3.1 Preparatory steps

- The first thing is to copy the files from the Dropbox link which was provided by the teacher. In this link, there is a directory called 'LISA' which contains several sub-directories called yyyymmdd, which represents the date of the observing run. Download (to your local computer) the data associated with the date of your observing run.
- The relevant Jupyter notebooks are also available in the Dropbox folder and are called:

```
LISA daytime reduction.ipynb
```

```
LISA nighttime reduction.ipynb
```

```
LISA spectra normalization.ipynb
```

Download them into your LISA data directory as well. The Dropbox folder will always contain the most recent version of the scripts.

- Sometimes an exposure is not useful, in particular one of your science targets (e.g., it was cloudy for a short while during the exposure). Such exposure will lower the quality of your data and should be removed from the data sample. Therefore, open each file individually. This can be done using DS9, which is commonly used in astronomy. It can be downloaded from

  https://sites.google.com/cfa.harvard.edu/saoimageds9

  You can open the file by simply clicking on it, although the first time you do this you likely have to link DS9 in such a way that it will indeed open fits files. Exam the image briefly and if all look fine close the image and open the next file. If the image does not look right, the best thing is to move this file to a separate sub-directory (e.g., called Failed) so that it will not be used further. **Do not delete them since you might need them still (e.g., for completing the report for the daytime observing run**. Go through all your files until you have manually checked all your data. Note that you also look at the calibration files (the Neon frames, flatfields, and the dark frames) and not only the science frames since also something might have gone wrong during the acquisition of these calibration data.

- The notebooks need a list of all the files in certain files (so-called meta-files) and you have to create these files (in any way you see fit):

  - *@dark.txt* → this file contains a list of all the dark frames you have obtained. If you have used multiple exposure times during your observing run, there will be different sets of darks, one set for each dark. Make sure that in this meta-file only dark rames are listed which have the same exposure. Make per exposure time a @dark.txt file (e.g., "@dark_20s.txt", if the exposure times are 20 s).
  - *@flat.txt* → this file contains a list of all the flatfields you have obtained.
  - *@neon.txt* → this file contains a list of all the Neon lamp frames you have obtained.
  - *@<object>.txt* → this file contains a list of all the frames you have obtained of your science target. <object> is self chosen name which represents what data is listed in this file (e.g., "@Horizon.txt"). If you have used different exposures times for the different targets, it might be useful to include the exposure times in the file names as well (e.g., "@Horizon_20s.txt"). This will make it easier later to associate the right dark files to the object data.

  A simple way of doing this is by opening the Command Prompt (for Windows users) and go, in the pop up window, to your directory containing the data (using the command "cd"). In there you can use the "dir" command to pipe a list of files to an ASCII file. E.g., if your darks frames are called Dark1, Dark2, etc, you can use the command "dir/b/d D* > @dark.txt" to create the @dark.txt file containing the file names of all your dark frames (you can check if it has worked by opening the resulting file). For Linux and MacOS users, open an xterm and go to the directory of your data.

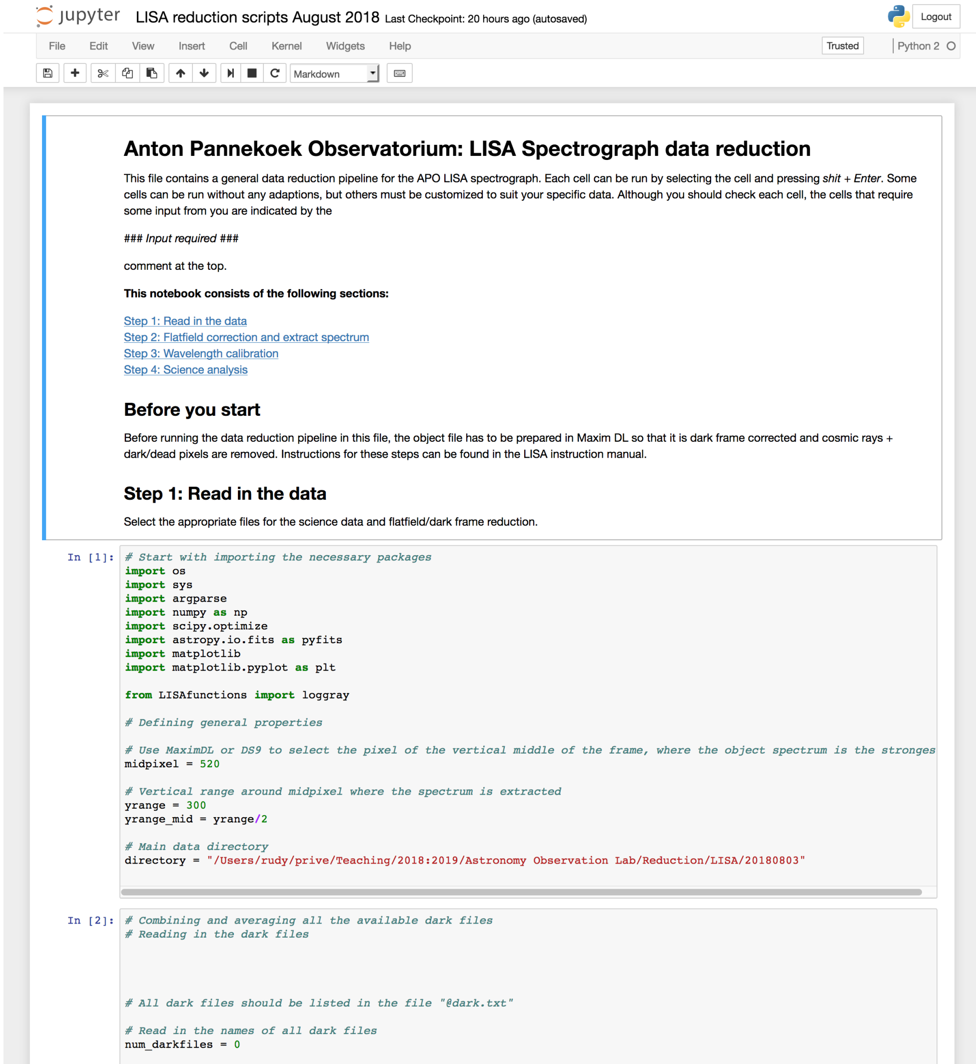

Fig. 21: *The Jupyter notebook interface at start-up.*

Using the command 'ls' you can make the necessary lists (e.g., 'ls Dark* > @dark.txt'). However, you can use any other method you prefer as long as the meta-files contain one file per line and are in ASCII format.

- To be able to run the notebooks, the notebook server as to run in the background. To start this server, first open the Command Prompt (Windoes) or an xterm (Linux/MacOS). Go to the directory of your data and type in "jupyter notebook". This will start the server and a separate (browser) window will appear with a directory structure. If indeed you are in your data directory, the notebooks should be visible in this list; if not, go to the directory in which you have stored the copies of the notebooks. Click on the notebook (one of the files ending in ".ipynb") you want to run. A screen will open that looks similar to what is shown in Figure 21.

3.2 Reduction in the Python notebook

The Jupyter Notebook working environment has a rather simple interface. If you never have used it then it might be beneficial if you do the in-build interface tour before you proceed further. To do this tour go to the Help tab and select 'User Interface Tour'. Also in the notebook itself some comments and more information is given about its working.

The notebooks consist out of individual cells which can be run individually. You can run a particular cell by clicking on this cell and press Shift+Ctrl (or Shift+Enter). The cells have to be ran in order but if a cell fails you can check the error, correct it and rerun the cell. The notebook server remembers the previous values that were obtained by running the cells.

When running cells frequently and sometimes not in sequence (e.g., because you want to alter a parameter which is defined in an earlier cell so you have to rerun that cell), it might happen that some parameters are not correctly set and weird results and/or errors might appear. Often the best thing to do is than to reset the Kernel. Go to the Kernel tab and click on 'Restart & Clear Output'. The full kernel is reset as well as all the output images have disappeared. Now you can (have to) rerun the notebook from scratch again.

Three different notebooks are available; one for the reduction of the daytime data, one for the nighttime data, and one to normalize spectra. The basic principles of the daytime and the nighttime scripts are the same, but the nighttime pipeline also extracts a background spectrum in addition to the source spectrum. The background is due to the sky which is not completely dark but has many emission lines as well. These lines show up also in the source spectrum and with the background spectrum you can identify which lines are due to the source itself and which one are due to the background[3].

The main steps of the notebooks will now be explained and when there is a significant difference between the nighttime reduction compared to the daytime reduction it will be pointed out.

3.2.1 Reducing the data

- **Step 1: Read in and plot the data**: The first few cells deal with reading in the data, averaging them, and plotting them (the meta-files should have been created in order for the cells too work properly; see Section 3.1). For the daytime data, basically the whole CCD is used to read out the source data. For the nighttime observing different read out regions on the CCD have to specified to read out the source data as well as the background data. How to specify these details is explained in Cell 1 where you also have to input other information (see below for details). In the cells the following steps are preformed:

  – Cell 1: Initialization of the necessary packages and defining several input values. If you miss a certain package, an error will appear. Use google to find out how to install the necessary package and install it.

    A main adjustment to do here is to adjust in the first cell the directory path to your data directory, which is in the variable called 'directory'. Other parameters to change are

[3]Source lines that are located at the same wavelength as certain background lines are very difficult to identify. Accurate estimation of the fluxes are then needed to determine if excess line flux is present at these wavelengths. However, this goes well beyond the goals of the lab.

- * *midpixel*: This is the ypixel value of the center of the source extraction region. You can use DS9 to determine where the center is of your source spectrum. Just open one of the 2D spectrum fits images and use the cursor to go to the center and read out the ypixel value.
  * *yrange*: This gives the ypixel range you want to use to extract your spectrum. For daytime observing this value is typically 300 meaning that most of the CCD will be used to extract the spectrum (basically there is no background spectrum because our source is very extended and covered the whole slit). Sometimes the slit was not fully horizontally placed during the observations causing the 2D spectrum to be a bit slanted as well. Make sure that the yrange is not too large so that it falls of the 2D spectrum. Usually the typical value of 300 for the daytime would work fine. You can play around with it a bit to see what happens later in the notebook. For nighttime observing you have to adjust this value because the source spectrum only covers a small range in the 2D image. Estimate (e.g, using DS9 in the opened 2D spectrum image) what the extend is of your source spectrum and change *yrange* to this value. This parameter will also be used to estimate the center of the background spectrum (the *midpixelback* parameter; you do not have to change this parameter).

- Cell 2-5: Here the data are read in, the source and background spectra (the latter only in the case of nighttime observing) are extracted, averaged, and then displayed. It also writes the number of frames averaged. In order: darks, flats, Neon frames, and science frames. **If you have used different exposure times for your objects, make sure that in Cell 2 you use the right dark metafile; the one that contains the darks that have the same exposure times as your science targets. In Cell 5, you have to set 'objectfiles' to the correct meta-file (e.g., "@Horizon.txt") in order to read-in the correct data.**.

  In Cell 5, the average science frame is also corrected for the dark current (the average dark frame is subtracted from the average science frame).

- Cell 6: For our purposes, this cell only puts the data into different arrays. However, this cell becomes more important if we would have had averaged master files obtained through other means. However, for our course this is not necessary. Just run the cell without adjusting anything in it.

• **Step 2: Flatfield correction**: Here the averaged science images are corrected by the average flat field and the spectra are plotted. The steps are:

  - Cell 7: Extract the average flat field spectrum from the 2D flatfield image and plot the resulting 1D spectrum. Clearly the resulting figure shows that the CCD is most sensitive at pixel $\sim$800 (around the middle of the CCD), with a sensitive decrease toward the edge of the CCD (most steeply toward blue wavelengths).

    The flat field spectra are also scaled to unity (also called "normalized" but this might cause confusion later on where we use "normalized" in a different way), with the brightest points given the value 1. The resulting spectra are plotted and it looks very similar to the previous figure but with scaled counts now instead of raw counts. From this figure you can immediately determine how relatively (in)sensitive we are at each pixel (thus each "wavelength" since pixels are directly related to wavelengths) is compared to the most sensitive pixel (e.g., around pixel 200, the CCD + LISA spectrograph combination has only a 10% sensitivity than around pixel 800)[4]. The scaled flatfield spectrum will be used to correct the source spectrum with (in Cell 8).

For nighttime data reduction, both the flatfield spectrum on the source position as well as on the background position are plotted. This clearly shows that also in the ypixel direction the CCD has not everywhere the same sensitivity. The latter is also highlighted in the extra plot that shows the division of the two flat fields. Depending on whether the background region that was used is located above or below the source region (this is automatically determined by the program), the curve might show values below or above 1. This curve is later needed (in Cell 9) to also correct for the sensitivity variation in the ypixel direction.

  - Cell 8: Here the source spectra are corrected by the scalled flat fields and plotted (orange color). The original, raw spectra are also plotted (blue) for comparison. For the nighttime data reduction the same is shown for the background spectrum as well as a final plot that shows the corrected source (blue) and background (orange) spectrum in one plot. If there are blue lines that are not accompanied by orange lines than this indicates that this line is a truly originating from the source and not due to the sky background.

- **Step 3: Wavelength calibration**: To convert a spectrum into one with wavelength units, it is necessary to know which pixel corresponds to which wavelength and we will use the Neon frames for this. Since the Neon spectral lines in the 2D calibration frames are both curved and slightly tilted, the function relating pixel to wavelength is 2-dimensional, depending on both x and y coordinates. This is taken into account in the notebooks. To apply the wavelength calibration follow the following step:

  - Cell 9: In this cell the Neon spectrum is extracted and plotted (see an example of such a spectrum in Figure 22, right). The default scaling of the y-axis is logarithmic but it can be set to linear as well by removing "plt.yscale('log')" (see Figure 22, left). Clearly many lines are visible in the figure, with nearly all of them toward the red part of the spectrum (toward higher pixel values) and only a few toward the blue part. As can be seen, some of the lines are saturated because they have a maximum value of $\sim$65 thousand (when averaged in the ypixel direction). For nighttime data reduction the Neon spectra at the source and the background position are extracted and plotted in the same figure. In addition, a zoom of the xpixel range 600-800 is shown. In this figure it is clear that the pixel-to-wavelength calibration is different for the source region than for the background region. Therefore, the final background spectrum cannot be straightforward be subtracted from the source spectrum. Therefore, we will keep working with the individual spectra.

  - Cell 10: In order to perform the wavelength calibration we need a line with a known wavelength that is not in crowded region and relatively central in the CCD. The best line for this is the line closest to xpixel 600 as seen in Figure 22, right. This line has a known wavelength of 5400.5616 Å. The notebook will search between xpixel 550 and 650 for the xpixel with the highest value and assumes this xpixel corresponds to the wavelength of this line. In case that the Neon spectrum is shifted compared to Figure 22, you have to adjust the *startx* value in the cell to make sure the program searches the right xpixel range. For the nighttime data

[4]This assumes that the flat field lamp has a homogeneous (flat) spectrum, but this is not the case. The intrinsic spectral shape of the flat field lamp is also folded into this plot but it is difficult to correct for this.

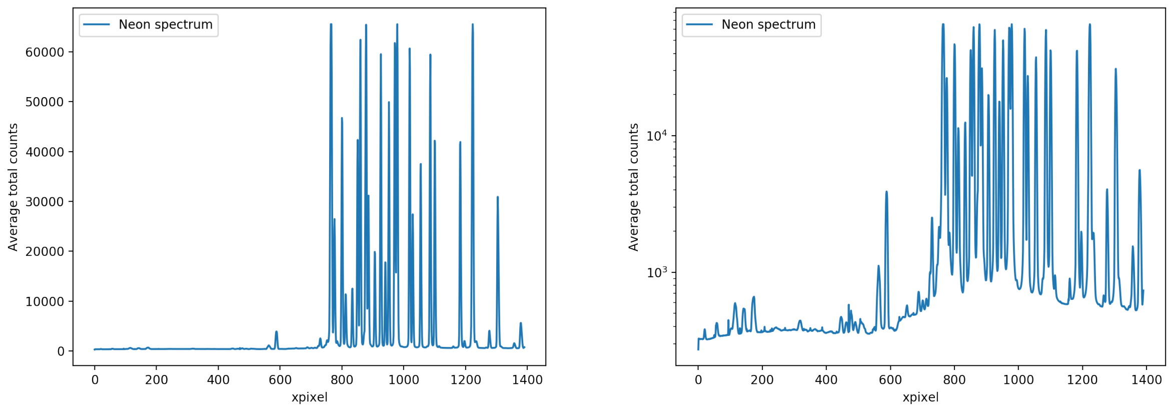

***Fig. 22**: A typical Neon spectrum (averaged in the ypixel direction) plotted with the y-axis with linear (left) and logarithmic (right) scaling.*

reduction, two figures are plot: one for the data extracted from the source region and one for the background region.

- Cell 11: In this cell, the program tries to identify a list of known lines in the Neon spectrum and determines at which xpixel they peak. The results are plotted. If everything is correct the resulting plot should resemble the one shown in Figure 23.

- Cell 12: The individual identified lines are fitted with a Gaussian function to determine the exact xpixel at which the lines peak. The resulting fits are plotted. Wait a few moments for the cell to finish before progressing to the next one. When investigating the plots, it is clear that some lines might not be well fitted (e.g., if the statistics of the lines are not very high or if some lines might be saturated). However, in general this should not affect the final wavelength calibration all that much. For nighttime data reduction, cell 12.a performed this procedure for the data extracted from the source region and cell 12.b from the data extracted from the background region.

- Cell 13: Here the pixel-to-wavelength calibration is applied to the flatfield corrected science frames and the final spectrum is plotted. For nighttime data reduction, cell 13.a performed this procedure for the data extracted from the source region and cell 13.b from the data extracted from the background region.

- Cell 14: The resulting final spectrum can be written to a file. You have to change the file name in this cell to write the output to the correct file. This file will be used in your further analysis.

- Cell 15: This cell is only there for the nighttime reduction part and in here the final source and background spectra are plotted. This figure is very similar to what is shown at the end of Cell 8 but now with the wavelength calibration applied. Using the *plt.xlim(6500,6800)* command you can zoom in to a certain wavelength range (in this case between 6500 and 6800 Å; this shows the region around the H_α line at 6564 Å).
- Additional cells: there are a few extra steps in the script. With those you can briefly do a very

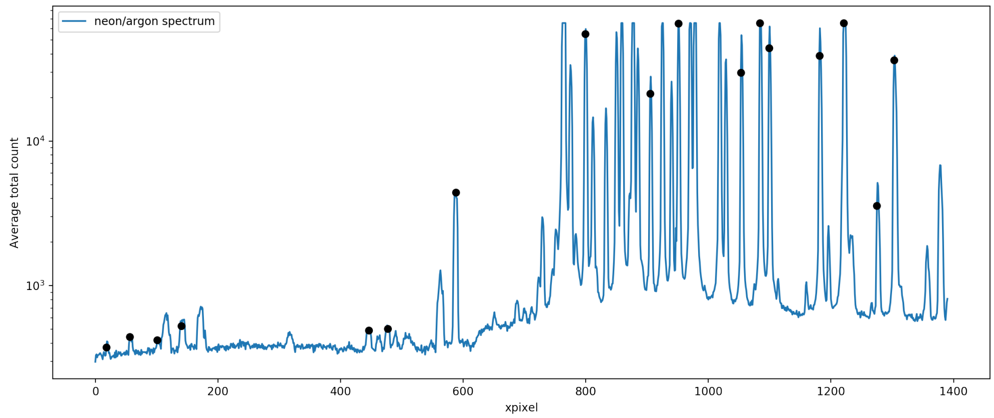

Fig. 23: *A typical Neon spectrum (averaged in the ypixel direction) plotted with the y-axis with logarithmic scaling. The line that were identified are indicated by a bullet.*

basic analysis on some of the spectral lines you see in the spectrum. However, we will use a more extended analysis script for this, which will be provided and discussed in separately.

3.2.2 Normalizing the spectra

The obtained spectra can be used in the analysis script. However, sometimes it might be useful to normalize the resulting spectra, i.e., when a strong continuum is present. Here normalisation means that we set the full continuum spectrum (at each wavelength; when not affected by any absorption or emission features) to unity. For example, you can normalize the daytime spectra and if you are working on spectra obtained from the Moon and the planets, you can also normalize the spectra.

Load the normalization notebook. This notebook contains 3 cells:

- Cell 1: Initialization of the necessary packages. Again, if you miss certain packages, use google to find the installation guides for these packages and install them on your computer.
- Cell 2: Defining of the necessary functions. There is typically no need to change anything here.
- Cell 3: This cell reads in the spectrum you want to normalize. Set 'directory' to the directory of your data and 'sf' to the name of the file that contains your spectrum. When executing this cell, it will plot the spectrum. With your left mouse button (or your right mouse button if you have a left-handed mouse) you can put point (red squares) on the spectrum. The program will search for the closest point in the spectrum. Be sure you do not put the point in an absorption line! The program is very basic and if you made a mistake you have to start over (although often clicking a point with the right mouse button could remove the erroneous point; note: this does not work for all users for unclear reasons). To restart it, you can type in 'r' or you can rerun the cell. When you are satisfied, type 'Enter/Return' and a spline is drawn through your points. If that looks fine, type 'n' and the spectrum will be normalized and it will be plotted. Type 'w' to write this output spectrum. It will have the same name as your input spectrum except that '.txt' is replaced by '_norm.txt'. This file will be used in your further analysis.

Note: The plotted spectrum might not always be interactive. This seems to happen at relatively random times and it appears a very hard to solve bug (in the sense that consistently the plot appears in interactive mode). Typically, rerunning the cell or even restarting the kernel eventually will produce an interactive plot.

4 Troubleshooting

- **EAGLE is off**
  - The EAGLE should be on which can be checked by looking at the lights at the side of the EAGLE. The ”PW” light should be on (Fig. 24, left). If the ”PW” light is off (Fig. 24, middle), push the ”Power on/off” switch (Fig. 24, right). The EAGLE will now start up. This can take several minutes.

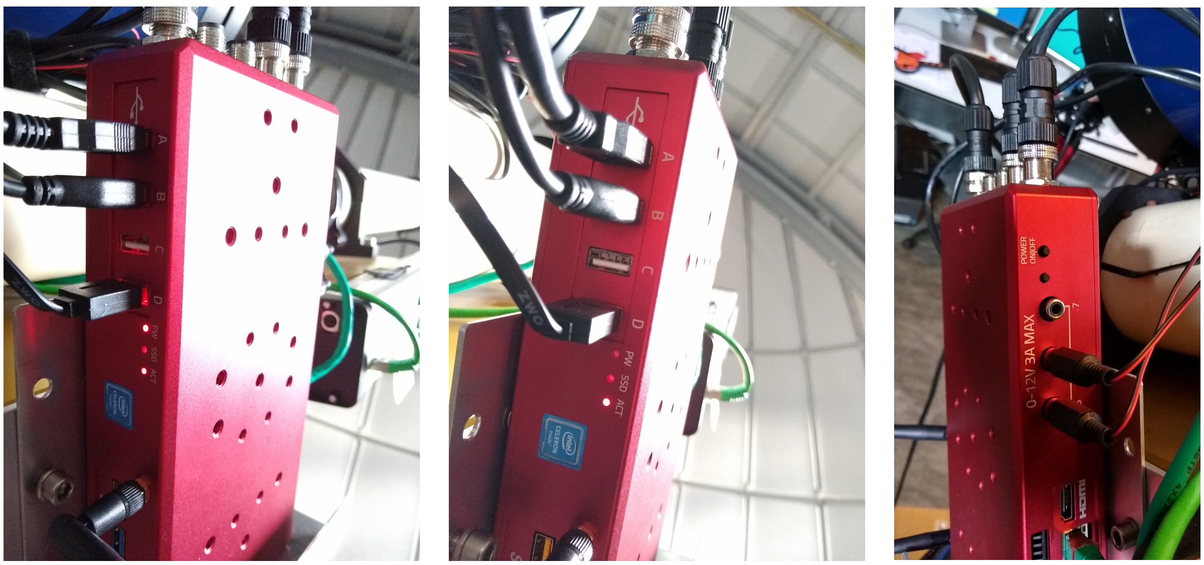

***Fig. 24**: Left: The ”PW” light is on indicated that the EAGLE is on. Middle: The ”PW” light is off so the EAGLE is not on. Right: at the other side of the EAGLE the power can be switched on pushing the ”Power on/off” switch*

- **MaximDL connection issue:**
  - For unknown reasons, MaximDL might hang when reading out the exposure and/or you might get an odd error message when try to expose. If that happens, disconnect the camera’s in the ”Camera Control” window. Physically unplug the data cables from the two CCDs of the LISA (both the red camera’s) and plug them back in. Reconnect the camera’s in the ”Camera Control” window and retry to take exposures.
- **MaximDL configuration issue:**
  - If somebody has by accident clicked ”Save” in the ”Configurations” window (Fig. 8 left), then the wrong settings might have been saved in the LISA configuration file. This then causes MaximDL to not correctly connect to the LISA. In that case, in the configuration window select the ’backup’ version of the needed configuration. Be very careful to push ’Load’ and not ’Save’! Check if MaximDL connect correctly now. Make a note in the APO log that MaximDL did not connect correctly and that this is how the problem is saved. Rudy and/or Rasjied will check the configuration the next day.

Fig. 25: *Guide image but with one of the calibration lamps still on. The light of the lamp shines under an angle into the guide image, hence one side is more exposed than the other side. Note that the slit is still nicely in focus, so this is not an issue with the guide camera itself (e.g., it is* **not** *out focus) but with additional light falling onto the guide image. See main text for solutions.*

- **Guide image:**
  - The guide image looks like as in Figure 25. This is because one of the calibration lamps are on and shining into the guide camera. If you are taking calibration data (flats and Neon lamp data), this is fine and you can just continue taking the calibration data. If, however, you wish to acquire observations of your target, then switch of the calibration lamps.
  - Slit is not horizontal: Loosen the ”Guiding lock” screw (Fig. 26) to be able to rotate the Guiding camera. Rotate until the slit is horizontal. Tighten the screw to fix the camera in place.
  - Slit/guide image is out of focus: Loosen the ”Guiding lock” screw (Fig. 26) to be able to move the Guiding camera in and out of it slot until the slit is in focus. Tighten the screw to fix the camera in place.

- **Neon frames:**

  The Neon lines do not fall on the same position of the CCD (e.g., when taking exposures at different times during the night): it is possible that the 'Focus Lock' button (Fig. 26) of the red cylindrical acquisition camera is not well tightened. You can tightened it. Note that when turning this button will very likely cause itself a shift of the lines and the obtained new calibrations lines might not be useful for data obtained before you tightened the button.

- **When all else fails:** Regularly things get stuck and whatever you do (either on the computers or with the hardware, like unplugging and plugging USB cables or other cables) you cannot revive a certain program (e.g., the camera connection is lost and you cannot restore it). In that case, the ultimate solution is to shut down all programs on the computer that can still be stopped and then reboot the computer and/or the EAGLE. Very often this will reset everything and things will work again. If that does not help either. Shut down the computer, the EAGLE, and shut down all hardware. After that, follow the restart procedure. If that also fails and the teaching assistant can also not solve the problem, write down as many details of the problem and add it to the APO observation log. Then shutdown and close everything correctly and go home. Rudy and/or Rasjied will try to solve the problem during the next day.

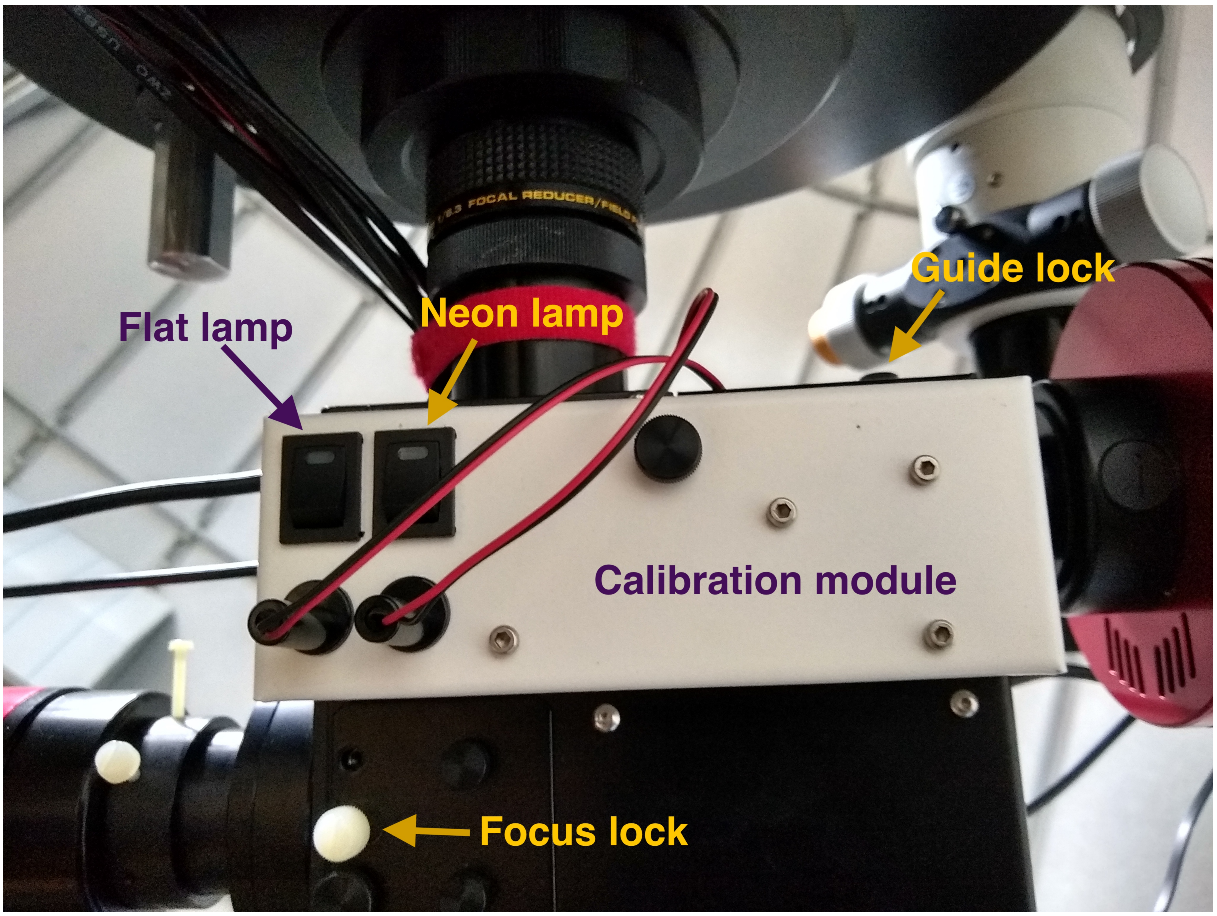

Fig. 26: *The back side of the LISA with the calibration module and the location of the "focus lock" and the "guide lock".*